On the Trust of Trusted Computing in the Post-Snowden Age

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Acknowledgment

Based (partly) on the following paper

Trusted Computing

- A broad term to refer to hardware-based security solutions
- Mainly driven by IT companies
  - 1999, started by Trusted Computing Platform Alliance (Compaq, HP, IBM, Intel and Microsoft)
  - 2003, succeeded by Trusted Computing Group (AMD, HP, IBM, Intel, Microsoft, etc)
- Initial focus on PCs
- Now increasing emphasis on mobile devices
“Rupert Murdoch ... referred consistently to his pride in the Sun as ‘a trusted news source.’ Trusted is the word he used, not trustworthy. We know the Sun is not trustworthy and so does he. He uses the word ‘trusted’ deliberately. Hitler was trusted, it transpired he was not trustworthy. He also said of ...”

– Russell Brand, in the Guardian, on Murdoch, the Sun, and the miserable state of the news industry
Different terminologies

- Microsoft renamed “Trusted Computing” to “Trustworthy Computing” (TC)
- But IBM and Intel stick to “Trusted Computing” (TC)
- Free Software Foundation calls “Treacherous Computing” (TC)
- In the end, the term “**Trusted Computing**” sinks in and is widely used
Controversies around Trusted Computing

- Many arguments against TC
  - Users lose control on privacy
  - Customer lock-in
  - Hinder free and open source software movement
- Like any other technology, TC can be used for good and bad
- In this talk, we focus only on technical aspects of TC
Essence of Trusted Computing

- Tamper-resistance
  - Tamper-resistant hardware with embedded CPU, secure memory
- Secure key storage
  - Secret keys always kept inside secure memory
- Key management
  - Via a set of APIs (most difficult part in the design)
Embodiments of Trusted Computing

- Trusted Computing Base (TCB), Trusted Platform Module (TPM), Hardware Security Module (HSM), Smart Card (contact/contactless, USB), Secure Element
A simple API example

- **Encryption**
  - Host $\rightarrow$ TPM: $m$
  - TPM $\rightarrow$ Host: $c = E_k(m)$

- **Decryption**
  - Host $\rightarrow$ TPM: $c = E_k(m)$
  - TPM $\rightarrow$ Host: $m$
How to ensure if the implementation is correct?

- The industrial practice
  - Unit testing
  - Test vectors

- The intuitive reasoning
  - If decryption always correctly recovers the original plaintext, the implementation should be correct.

- We argue this is not sufficient in face of state-funded adversaries.
A trapdoor attack

- TPM compresses the message before encryption, and adds a trapdoor block to make equal length
  - Trapdoor block is the decryption key wrapped under a trapdoor key
- Assume encryption schemes are semantically secure
  - Ciphertext is indistinguishable from random
  - The attack is undetectable
Why would any TPM manufacturer do that?

- **Incentive**
  - Manufacturers appear to have no incentive to compromise security of their own products
  - But a state-funded adversary may have the incentive to coerce/bribe manufacturers to do that

- **Revelations from Snowden**
  - NSA has been trying to insert trapdoors into security products
  - Actually, any state-funded adversary would do just the same
Trapdoor in Trusted Computing - truth or rumor?

- How can you possibly tell?
  - No access to internal software thanks to tamper resistance
Learning from the history

- Similar trust crisis on electronic voting
  - DRE records votes and announces the winner
  - Voters have to trust the outcome, but can’t verify
  - Public outcry as no way to check internal software

- Solution: trust-but-verify
  - “Software Independence” (Ron Rivest, John Wack)
  - Verify the integrity of voting software by checking its output, not its source code
  - Underpinning 20 years research on verifiable e-voting
Our proposal: apply Trust-but-Verify to redesign TC API

- In the post-Snowden age
  - The threat of state-funded adversary cannot be ignored
- Apply “trust-but-verify” principle
  - Many existing APIs need to be re-designed
An example: data encryption

- Suppose we build TPM-based disk encryption
  - Using Diffie-Hellman Integrated Encryption Scheme (DHIES)
- DHIES
  - Abdalla, Bellare and Rogaway (CT-RSA, 2001)
  - Included in standards of ANSI X9.63, IEEE P1363a and SECG
Overview of DHIES

- v·G: User's public key
- Make secret value
- u: Make ephemeral PK
- u·G: Ephemeral public key
- Secret value: u·v·G
- H: macKey, encKey
- tag
- encM
- M
- E
- T
System architecture

- **API calls**
  - Key Generation
  - Encryption
  - Decryption

- Other APIs omitted (e.g., authentication, key revocation)
Key Generation

Key generation:

```
Host  →  TPM  :  $1^k, C$
TPM  :  Generate $Prv_{Ci} := d_{Ci}$
TPM  →  Host  :  $Pub_{Ci} := d_{Ci} \cdot G, C_i$
```
Encryption/Decryption

Encryption:

\[ \text{Host} \rightarrow \text{TPM} : \quad C_i, \ m \]
\[ \text{TPM} \rightarrow \text{Host} : \quad Q_\eta := d_\eta \cdot G, \ H(k_c), \ E_{k_\eta}^{\text{Auth}}(m) \]

Decryption:

\[ \text{Host} \rightarrow \text{TPM} : \quad C_i, \ Q_\eta, \ H(k_c), \ E_{k_\eta}^{\text{Auth}}(m) \]
\[ \text{TPM} \rightarrow \text{Host} : \quad m \]
State-funded adversary

- This design is trivially subject to the trap-door attack
- A state-funded adversary is able to read all encrypted traffic
Applying trust-but-verify

Audit:

Host $\rightarrow$ TPM : $C_i, Q_\eta, H(k_c)$
TPM $\rightarrow$ Host : $d_{C_i} \cdot Q_\eta, \ldots$

ZKP$_\eta [\log_G d_{C_i} \cdot G = \log_{Q_\eta} d_{C_i} \cdot Q_\eta]$

- Explicitly verify if encryption was done properly
- Based on Chaum-Pedersen ZKP
- More details in the paper
Full implementation on a resource-constrained Java Card
A non-trivial implementation challenge
Java Card code published in public domain (see paper)
We started a small step, but it will be a long journey.

Many research questions remain: e.g.,

- How to ensure if the random number is generated correctly
Summary

- Existing assumptions about Trusted Computing
  - Either complete trust or totally distrust (i.e., black/white)
  - However, neither captures realistic requirements

- We propose “trust but verify”
  - A well accepted principle in 20 years e-voting research
  - But almost entirely neglected in the field of Trusted Computing

- Future work
  - Re-design existing TPM APIs based on the new principle
  - Many open research problems, e.g., random number generation
Thank you!

For more technical details, see https://eprint.iacr.org/2014/364.pdf